MECHANISMS OF VARIATIONS IN HEAT EMISSION IN THE THERMONEUTRAL ZONE IN RABBITS

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Variations in heat production (thermoregulatory muscle tone) with a period of 10-20 min, found in the thermoneutral zone of rabbits, coincide in period and direction with variations in heat emission from the concha auriculae (and in their temperature) in the animals. These variations can be linked with reflex effects from muscle proprioceptors. Besides specific thermoreceptors, the muscle proprioceptors evidently play a direct part in the maintenance of temperature homeostasis and ensure maximal rapidity of action of the thermoregulatory system within this temperature range.

Constant variations in the temperature of the concha auriculae with an amplitude of 0.5-7°C and a period of 10-20 min (variations in heat emission) and variations in the temperature of various parts of the brain and arterial blood, opposite in phase, have been found in rabbits in the thermoneutral zone (22-28°C) [5, 7]. Within the temperature range of 20-30°C heat production by homoiothermic animals is minimal [10, 11]; its magnitude is determined chiefly by the energy metabolism of the internal organs [8]. In the thermoneutral zone metabolism of the internal organs is relatively stable [8, 9, 12]. An extremely important mechanism of chemical thermoregulation is the thermoregulatory tone of the skeletal muscles. However, no data reflecting the behavior of thermoregulatory muscle tone within the thermoneutral zone could be found in the literature.

In the investigation described below an attempt was made to elucidate the mechanisms of variations in heat emission from the conchae auriculae of rabbits and to analyze the behavior of the thermoregulatory muscle tone within this temperature zone.

EXPERIMENTAL METHOD

Chinchilla rabbits weighing 2.5-3.5 kg were used. Under pentobarbital anesthesia a copper–constantan thermocouple 0.2 mm in diameter was inserted by means of a stereotaxic apparatus into the region of the hypothalamus corresponding to coordinates A_3, $L_{1.5}$, H_{13} of Sawyer's atlas [14]. During the experiment the temperature of the concha auriculae, the hypothalamus, and the rectum at a depth of 6 cm was measured [2]. The thermoregulatory muscle tone was measured and recorded by means of the UBPI-01 biopotentials amplifier, the input of which was connected to two needle electrodes inserted subcutaneously above the test muscle, 2.5 cm apart. The signal from the amplifier was led to the input of an integrator [4] giving pulses at its output with a frequency proportional to the integral of the input signal. To record the temperatures and the thermoregulatory muscle tone simultaneously on the tape of a 12-point ÉPP-09 potentiometer the output of the integrator was connected to the input of an ISS-3 mean count rate meter, giving an output signal in the form of voltage. So that the changes in thermoregulatory tone had the greatest span on the potentiometer tape, compensation of the constant component was introduced.

During the experiment the rabbit was kept in a constant-temperature chamber measuring 7 m^3, in a special frame which restricted its movements. The chamber was fitted with cooling and heating systems to provide the required ambient temperature.

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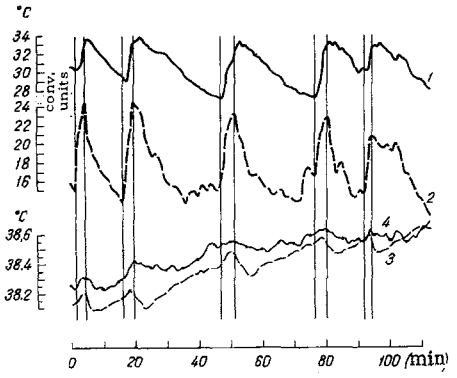

Fig. 1

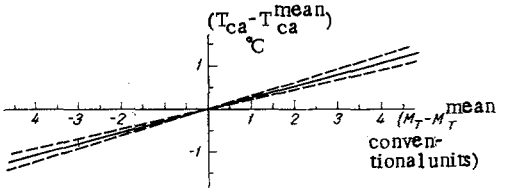

Fig. 2

Fig. 1. Cut from experimental record of electrical activity from rabbit's spinal muscles: 1) temperature of concha auriculae; 2) thermoregulatory muscle tone; 3) temperature of hypothalamus; 4) temperature in rectum. Verticle lines mark beginning of increase and decrease in thermoregulatory muscle tone.

Fig. 2. Geometrical interpretation of relationship of direct proportionality between temperature of concha auriculae and thermoregulatory muscle tone. Broken lines mark limits for coefficient of proportionality K, determined by the standard deviation (explanation in text).

EXPERIMENTAL RESULTS

Twelve experiments, each lasting several hours, were carried out on four animals. Thermoregulatory tone was recorded from the muscles of the spine or neck.

In the thermoneutral zone the thermoregulatory muscle tone was found to vary constantly with a period of 10-20 min. The period of its variations coincided with the period of variations in temperature of the animal's concha auriculae. The variations also coincided in direction: with an increase in temperature of the concha auriculae the thermoregulatory muscle tone increased at the same time. The internal temperatures of the animal's body (hypothalamic and rectal) as a rule showed a tendency to increase (by 0.3-0.6°C in 4-6 h) in the thermoneutral zone; i.e., this temperature zone is a zone of "mild overheating" for the rabbit. On this slow increase of central temperatures are superposed variations with a period of 10-20 min and an amplitude of 0.1-0.3°C, in the opposite direction to the variations in temperature of the animal's concha auriculae. A record of one experiment is given in Fig. 1.

An attempt was made by statistical methods to determine the relationship between the heat emission (temperature) and the heat production (thermoregulatory muscle tone) assuming constant heat production of the internal organs. Statistical analysis of the results (425 measurements of each parameter with a step of 2.5 min) was carried out on the Dnepr-21 computer. The relationship between the temperature of the concha auriculae and the thermoregulatory muscle tone was determined from the equation

$$T_{ca} - T_{ca}^{mean} = K \times (M_T - M_T^{mean})$$

where K is the coefficient of proportionality (in deg/conventional units), T_{ca} the temperature of the concha auriculae (in °C), T_{ca}^{mean} the mean temperature of the concha auriculae for all measurements (in °C), M_T the thermoregulatory muscle tone (in conventional units), and M_T^{mean} the mean value of the thermoregulatory muscle tone for all measurements (in conventional units). The method of least squares was used. To determine the coefficient K, uncorrelated values of M_T were used. For the data obtained, K = 0.28 ± 0.04 deg/conventional unit (M ± σ). A geometrical interpretation of the resulting function is shown in Fig. 2.

To maintain thermal equilibrium between heat emission and heat production, the mechanisms of physical and chemical thermoregulation function simultaneously and in opposite directions. For example, with a decrease in the ambient temperature the heat production rises (thermoregulatory tone and shivering) while the heat emission is reduced by vasoconstriction of the peripheral vessels.

Within the range of ambient temperatures investigated the rabbit's heat production varied constantly. The variations in heat production and heat emission had the same period and were in the same direction.

A relationship of direct proportionality was found between heat emission and heat production. The central temperatures in the thermoneutral zone varied in the opposite direction to the variations in temperature of the rabbit's concha auriculae, as other workers have observed [5, 6, 11, 13].

Variations in thermoregulatory muscle tone are presumably one cause of the periodic dilatations and constrictions of the vessels of the rabbit's concha auriculae. According to the available evidence [8], an increase in muscle tone causes an increase in the temperature of the muscles and blood, and through the blood, an increase in the temperature of the various thermosensitive structures of the nucleus, especially the hypothalamus, which contains specific thermosensitive neurons. Work in the author's laboratory [6, 7] has shown that the threshold of sensitivity of the hypothalamus to its own temperature is considerably lowered in the rabbit within the thermoneutral zone, and on this basis it has been postulated that changes in the temperature of the hypothalamus are the possible cause of variations in heat emission from the rabbit's concha auriculae. The results of the present series of experiments do not contradict this view. However, analysis of the temporal relations between the temperature of the concha auriculae, the muscle tone, and the central temperatures (hypothalamic, rectal) suggests that the mechanisms of the variations in heat emission from the concha auriculae are not limited to those mentioned above.

Since changes in muscle tone (Fig. 1) precede changes in the central temperatures and changes in the temperature of the concha auriculae, the existence of direct reflex effects on the thermoregulatory center from the muscle proprioceptors can be postulated. Within the thermoneutral zone, where temperature homeostasis is maintained with high accuracy on account of the reflex connection between heat production and heat emission, this regulation is effected with maximal rapidity.

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